Remarks

Claims 1-23 are pending. Claims 1-15 and 20-23 have been withdrawn from consideration. Claim 16 has been amended to correct a minor typographical error. The word "an" has been replaced with the word "a." Applicants note that this amendment was not made earlier, as the error was just recently discovered. Applicants respectfully request entry of this amendment, as it is believed to generate no additional burden on the Patent Office.

§ 112 Rejections

Claims 16-19 stand rejected under 35 USC § 112, first paragraph, as purportedly failing to comply with the written description requirement. The Patent Office alleges that the specification does not disclose the conductive bumps being metallurgically bonded to the integrated circuit chip. (Paper No. 18, page 2.).

It is well settled law that a specification complies with the written description requirement of 35 USC § 112, first paragraph, if it conveys with reasonable clarity to those skilled in the art that, as of the filing date sought, the inventor was in possession of the invention. See, e.g., Vas-Cath, Inc. v. Mahurkar, 935 F.2d 1555, 1563-64 (Fed. Cir. 1991); MPEP § 2163.

A careful review of the Patent Office argument proves that the § 112, first paragraph requirements are more than adequately fulfilled. More specifically, the Patent Office stated:

> The specification, as originally filed, does not disclose that *the conductive bumps being metallurgically bonded to the integrated circuit chip*, as recited in amended claim 16. In fact, Applicants' specification recites that: "the IC may be metallurgically bonded to the substrate" (Applicants' specification, page 1, line 32 and page 2, line 1)...

See 03/25/04 Office Action page 2. Thus, the Patent Office admits that "metallurgically bonded" is described and that such a bond is described as located between the IC and the substrate. Of course, the process of metallurgically bonding an IC to the substrate cannot happen if the conductive bumps are not metallurgically bonded to the IC in the first place. What material carries out the function of metallurgically bonding? It is the conductive bumps, also described as solder balls. While Applicants could cite any number of references for this aspect, it appears that

the Patent Office already admits that the specification fully describes this as well. For example, the rejection further states that:

> *A typical assembly process for flip-chip assembly involves the following steps: 1) flux paste is applied to the substrate bond pads; 2) the IC is aligned and placed on the substrate while the tackiness in the flux holds the chip in place; 3) the assembly is passed through the reflow oven and* ***the solder melts and bonds metallurgically*** *with the substrate pads; and 4) the sample is passed through a flux cleaning operation*" (page 2, lines 21-26).

See 03/25/04 Office Action pages 2-3 (bold font added). Thus, the Patent Office admits that the specification describes how the conductive solder bumps bond metallurgically to the integrated circuit chip. In this case, not only does the specification conveys with reasonable clarity to those skilled in the art that the inventors were in possession of the invention, the Patent Office citations appear to demonstrate this fact. Thus, the rejection under 35 USC § 112, first paragraph, is unwarranted and should be withdrawn.

Further, it is noted that to satisfy the written description requirement, a patent specification must describe the claimed invention in sufficient detail that <u>one skilled in the art</u> can reasonable conclude that the inventor had possession of the claimed invention. (MPEP § 2163(I), emphasis added.) The subject matter of the claim need not be described literally in order for the disclosure to satisfy the description requirement. (MPEP § 2163.02.) Rather, limitations may be supported in the specification through express, implicit, or inherent disclosure. (MPEP § 2163(II)(A)(3)(b).)

Applicants note that the specification at page 2, lines 17-20 describes the process by which solder bumps are placed on the integrated circuit chip. Specifically, solder is preapplied to the connection pads of the chip and is reflowed to form a nearly spherical bump prior to final board assembly. Applicants respectfully submit that anyone of ordinary skill in the art of flip chip assembly understands that the creation of a metallurgical bond between the solder bump and the chip is inherent in the disclosed process. For example, Applicants' specification sufficiently describes this procedure (*i.e.*, placing solder bumps in contact with a pad and conducting a solder reflow process) as creating metallurgical bonds. (See page 1, line 30 – page 2, line 1.) See, also, the following references, copies of which are attached for the Examiner's convenience:

(1) Surface Mount Technology: Principles and Practice; Prasad, R.P., Van Nostrand Reinhold, NY (1989) pp. 349 and 423.

(2) Curtailing Voids in Fine Pitch Ball Grid Array Solder Joints; Morrison, G., and Lyne, K., SMT Express Vol. 2, Issue 3 (March 16, 2000) (see, e.g., page 3 of 10). (http://www.smtnet.com/express/200003/voids/index.cfm - last accessed May 14, 2004.)

(3) Guidelines for Soldering Surface Mount Components to PC Boards; Rosenfield, M., intersil ™ Technical Brief TB334.2 (October 2000). (http://www.intersil.com/data/tb/tb334.pdf - last accessed May 14, 2004.)

In summary, Applicants respectfully submit that persons skilled in the art would recognize in the original disclosure a description of the invention described by the presently pending claims. Thus, the rejection of claims 16-19 under 35 USC § 112, first paragraph, is unwarranted and should be withdrawn.

§ 103 Rejections

Claims 16-19 stand rejected under 35 USC § 103(a) as purportedly being unpatentable over Matsubara et al. (JP-402023623A) in view of Japan patent JP-07130749A (JP-749). In preparing the comments below, Applicants used a machine translation of JP-749, a copy of which has been attached for the Examiner's convenience.

The present invention provides an integrated circuit chip comprising a bumped side having a passivation surface on which a plurality of conductive bumps are disposed such that these bumps comprise a metallurgical bond with the integrated circuit chip. Such bond structure can be formed with, e.g., an elevated temperature reflow process (see, e.g., page 1, line 28 to page 2, line; page 2, lines 17-20; and page 7, lines 4-6). The conductive bumps are selected from the group consisting of: solder, meltable solid metals, gold, electroless nickel, electroless gold, and combinations thereof. A layer of adhesive covers the bumped side of the integrated circuit chip, and has a primary surface that is substantially parallel to the passivation surface. The conductive bumps have exposed contact regions having a rounded profile that are not covered by the adhesive.

The Patent Office acknowledges that Matsubara fails to teach conductive bumps that are metallurgically bonded to the integrated circuit chip. (Paper No. 18, page 4.) The Patent Office

then asserts that JP-749 teaches a metallurgically stabilized bond formed by pressure welding. The Patent Office further asserts that it would have been obvious to one of ordinary skill in the art at the time the invention was made to apply the JP-749 teachings to Matsubara's device in order to reduce damage on the joining part. Applicants respectfully traverse.

First, JP-749 describes a method for forming stud bumps (nail head bumps). (See [0009], [0018], and Drawing 3, 4, 6, and 9.) As these bumps do not have a rounded profile, the combination of these bumps with Matsubara would not describe, teach, or suggest all of the elements of the claimed invention.

Second, JP-749 describes a process for forming stud bumps on an electrode involving the following steps. First, a spherical piece of metal is formed at the tip of a capillary tube. Next, the sphere is brought into contact with the electrode and deformed to form a nail head or stud bump. The metal is adhered to the electrode by ultrasonic sticking-by-pressure (e.g., thermocompression bonding, or ultrasonic thermocompression bonding). (See, e.g., [0029] – [0046], and Drawings 4 and 6.)

Matsubara explicitly discussed such metal to metal bonding noting that this requires the electrodes to be made of a material having an affinity for the bump material (e.g., gold) and that such connections are **poor**. (Page 3, lines 19-26, emphasis added.) Matsubara purports to provide a new method of bonding a chip to a board, which uses an adhesive layer that would overcome these problems. (See, page 4, lines 18-281.) Thus, applicants respectfully submit that Matsubara expressly teaches away from the method of JP-749, and therefore the references cannot be combined to establish a *prima facie* case of obviousness. (MPEP § 2145(X)(D)(2).)

Finally, the method of Matsubara is characterized by including a process during which an adhesive layer is formed over the main body of an electrode. (Page 4, lines 25-27.) Subsequently, conductive particles are adhered to the adhesive layer. (Page 4, lines 34-36.) Applicants respectfully submit that the application of an adhesive over the main body of the electrode (as required by Matsubara) is contrary to the teaching of JP-749 that the metal sphere is brought into pressure contact with the electrode. Therefore, the Patent Office's proposed combination contradicts the express teachings of the references and would render the references unsatisfactory for their intended purposes. (See, MPEP § 2143.01.)

For at least these reasons, the rejection of claims 16-19 under 35 USC § 103(a) as being unpatentable over Matsubara et al. (JP-402023623A) in view of Japan patent JP-07130749A (JP-749) is unwarranted and should be withdrawn.

Claims 16-19 stand rejected under 35 USC § 103(a) as purportedly being unpatentable over Matsubara et al. (JP-402023623A) in view of Yeh (U.S. Patent No. 5,607,099).

As discussed, the Patent Office has acknowledged that Matsubara fails to teach conductive bumps that are metallurgically bonded to an integrated circuit chip. (See Paper No. 18, page 6.) The Patent Office asserts that a conductive bump being metallurgically bonded to an integrated circuit chip is conventionally applied in semiconductor art as taught by Yeh. The Patent Office further asserts that it would have been obvious to apply the metallurgical bonding process to Matsubara. (Paper No. 8, page 6.) Applicants respectfully traverse this combination.

First, Yeh describes a method of forming solder bumps on a carrier and transferring the bumps to a circuit chip. (Col. 2, lines 32-35.) Matsubara discussed the deficiencies solder bump transfer methods such as those described by Yeh (page 3, lines 9-25) and purports to provide a process which overcomes these deficiencies. (Page 3, lines 26-31.) Thus, Matsubara expressly teaches away from the method of Yeh. Applicants respectfully submit that the Patent Office has failed to present anything in Matsubara or Yeh that would lead one of ordinary skill in the art to ignore Matsubara's explicit teaching and combine the references as suggested.

Second, as shown in FIG. 1, and described by Yeh at col. 5, lines 14-26, the formation of a metallurgical bond between solder ball and the flip chip requires the molten solder to wet and transfer to the flip chip. In contrast, the process of Matsubara requires an adhesive layer over the electrode prior to the introduction of the conductive particles. (Page 4, lines 25-26.) Applicants respectfully submit that Matsubara and Yeh could not be combined as suggested by the Patent Office, as the adhesive layer of Matsubara would prevent the solder balls of Yeh from contacting and wetting the electrodes. That is, Matsubara and Yeh could not be combined to achieve all elements of the claimed invention without destroying the functionality of one or both references.

For at least these reasons, the Patent Office has failed to establish a *prima facie* case of obviousness. Therefore, the rejection of claims 16-19 under 35 USC § 103(a) as purportedly

being unpatentable over Matsubara et al. (JP-402023623A) in view of Yeh (U.S. Patent No. 5,607,099) is unwarranted and should be withdrawn.

In view of the above, it is submitted that the application is in condition for allowance. Reconsideration of the application is requested and entry of the amendment correcting the typographical error also is requested. Allowance of claims 16-19, as amended, at an early date is solicited. The Examiner also is invited to contact the undersigned attorney to resolve any remaining issues.

Respectfully submitted,

18 May 2004
Date

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Enclosures: Machine Translation of JP-07130749A
<u>Surface Mount Technology: Principles and Practice</u>
<u>Curtailing Voids in Fine Pitch Ball Grid Array Solder Joints</u>
<u>Guidelines for Soldering Surface Mount Components to PC Boards</u>

PATENT ABSTRACTS OF JAPAN

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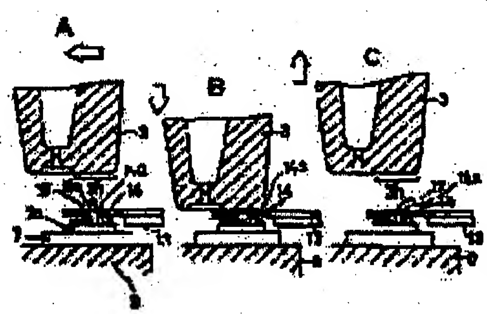
(54) APPARATUS AND METHOD FOR JOINTING OF LEAD OF ELECTRONIC COMPONENT



(57)Abstract:
PURPOSE: To form a highly accurate and high quality bump on an electrode pad by compression bonding, reduce the damage of a jointed member when a lead is jointed with the jointed member, perform accurate alignment and, further, perform the attraction and feed of a metal ball, the formation of the bump and the calking joint with one tool.
CONSTITUTION: A highly accurate and high quality metal ball which is formed beforehand metallurgically stably is selectively attracted by the tip part of a capillary tool 3 and the metal ball is deformed by compression on a compression-bonded member such as an electrode pad 7a to form a nail head shaped bump 16. Further, the center hole 14a of a lead is retained with the center protrusion 16a of the bump 16 and the calking joint is performed by compression with the pressing flat part 3h of the capillary tool 3.

/

[Claim(s)]
[Claim 1] the above of the tube part for adsorbing the spherical piece of a metal, and the above-mentioned tube part -- abbreviation prepared near adsorption opening prepared in the end section of the side which adsorbs the spherical piece of a metal, and the above-mentioned adsorption opening -- the lead junction equipment of the electronic parts which have the flat sticking-by-pressure formation section.
[Claim 2] The end face of a top Norikazu edge is lead junction equipment of the electronic parts according to claim 1 characterized by to have arranged in parallel the 1st circle and 2nd circle, to have considered as the shape of an ellipse which connected between the 1st circle of the above, and the 2nd circle of the above at the flat surface, and to consider as the relation in which the above-mentioned adsorption opening is prepared in the core of the 1st circle of the above, and the above-mentioned adsorption opening is not contained in the 2nd circle of the above.
[Claim 3] It is lead junction equipment of the electronic parts according to claim 2 characterized by being formed in the place which separated the core of the 2nd above-mentioned elliptical circle of the above from the core of the 1st circle of the above more than the path of the ball the piece of a metal of the above in the end face of a top Norikazu edge.
[Claim 4] The lead junction equipment of electronic parts characterized by providing the following is used. Ball the piece of a metal of the above is chosen from the group which consists of Metals Au, Ag, and Cu and eutectic alloy Au-Sn, Sn-Pb, and In-Pb, and it sticks to the above-mentioned adsorption opening. Ball the piece of a metal of the above to the member stuck by pressure thermocompression bonding or by carrying out ultrasonic thermocompression bonding The bump formation approach for electronic-parts junction in which the bump who has the projection of the shape of a back taper for carrying out sticking-by-pressure junction in the center was formed The tube part for adsorbing the spherical piece of a metal Adsorption opening prepared in the end section of the side which adsorbs ball the piece of a metal of the above of the above-mentioned tube part abbreviation prepared near the above-mentioned adsorption opening -- the inner skin of the shape of a taper to which is resembled, and is followed and a path decreases which consists of the flat sticking-by-pressure formation section, and separates from the above-mentioned adsorption opening
[Claim 5] furthermore, the hole of a lead of a TAB film is engaged with the above-mentioned bump's above-mentioned projection -- making -- the above-mentioned abbreviation -- the lead caulking junction approach of the electronic parts according to claim 4 characterized by carrying out caulking sticking-by-pressure junction by the flat sticking-by-pressure formation section.
[Claim 6] the above-mentioned abbreviation after forming the above-mentioned bump -- the bump formation approach for electronic-parts junction according to claim 4 of having been made to perform bump equalization which arranges the above-mentioned bump's height by the flat sticking-by-pressure formation section.

[Detailed Description of the Invention]
[0001]

[Industrial Application] This invention is applied when joining the case where a bump is formed on the electrode pad of an electronic-circuitry component like IC chip at the lead junction equipment list of electronic parts, concerning the lead junction approach, and a lead to an electrode pad, and it is suitable.

[0002]

[Description of the Prior Art] Drawing 7 is the important section perspective view of the ultrasonic thermocompression bonding equipment used for the ultrasonic thermocompression bonding junction by the conventional wire ball bonding method, and drawing 8 is the enlarged drawing of the part which performs junction in drawing 7 . The ultrasonic thermocompression bonding junction technique by this wire ball bonding method is widely known from the former as a technique which joins the electrode pad and leadframe of detailed IC chip. The outline of this conventional technique is explained according to drawing 7 thru/or drawing 10 .

[0003] In drawing 7 and drawing 8 , the capillary tube tool 103 is being fixed to the beam 102 which built in the ultrasonic generator 101 with the conclusion screw 104. And the revolving shaft 105 attached in the tank of an ultrasonic generator 101 is supported at the both ends of a pedestal 106, and the capillary tube tool 103 is pivotable in the fixed range centering on the revolving shaft 105 by this. The golden wire 107 is beforehand inserted in the capillary tube tool 103, and melting formation of the wire golden ball 107a is carried out by a hydrogen torch or high-pressure discharge at the point. And where the IC chip 108 which attached electrode pad 108a to the direct lower part of this wire golden ball 107a is joined to a substrate 109, it is carried on heating apparatus 110, and the front face of that electrode pad 108a is heated by laying temperature.

[0004] while position control of the capillary tube tool 103 is carried out in the XY direction under such conditions -- electrode pad 108a of the IC chip 108 -- it is mostly moved in the center and positioning is completed. Then, the capillary tube tool 103 begins to descend and supersonic vibration and a sticking-by-pressure load concentrate on coincidence through an ultrasonic generator 101 just before sticking by pressure at wire golden ball 107a. As wire golden ball 107a of drawing 9 A shows with the sign 111 of drawing 9 B, deformation sticking by pressure is carried out by this, and it is joined to electrode pad 108a by it by the shape of a nail heading.

[0005] By the way, since it is necessary to perform wiring by connecting for two points and continuation penetration of the golden wire 107 is carried out originally at capillary tube 103a (drawing 9 A) at the capillary tube tool 103 of an above-mentioned condition, wiring can be freely constructed by considering the capillary tube tool 103 as a guide, and it is the thing with a leadframe 112 whose junction wiring of wire rod sticking by pressure is attained like drawing 7 .

[0006] However, in this conventional technique, since wire golden ball 107a was crushed on electrode pad 108a and junction wiring was carried out, the limitation was generated to make the pitch of electrode pad 108a small, and it had become the hindrance of detailed-izing of the IC chip 108. Moreover, since the expensive golden wire 107 was used for wiring, there was also a problem that a manufacturing cost went up. In addition, since junction by the side of the leadframe 112 of the golden wire 107 was not performed by having crushed ball-like gold but was performed by crushing the golden stroke material itself, it could not enlarge the area compared with the junction by the side of electrode pad 108a, but also had the problem that dependability fell.

[0007] Furthermore, it sets to the capillary tube tool 103 of drawing 9 A. Since the tip of the golden wire 107 is fused by the hydrogen torch or high-pressure discharge and wire golden ball 107a is formed Since the golden wire 107 near right above [of it] and the nail heading wire bump's 111 (111a, 111b, 111c, 111d) surface part made by carrying out sticking-by-pressure deformation serve as a recrystallization field influenced [thermal], If the wiring loop formation after sticking by pressure is made low across a limitation, a wrinkle and a crack will come to occur frequently in the neck section. In the time of the mold after a wire-bonding process etc., it becomes easy to cause the accident of fracture of a ball neck part with the stress of resin, and there was a problem of spoiling the dependability of a semiconductor device to the degree of pole.

[0008] For this reason, wiring of an expensive golden wire which was needed with the above-mentioned conventional wire ball bonding technique is lost, and the wafer bump technique and the imprint bump technique are proposed as a technique which moreover narrows the pitch of an electrode pad and makes high density assembly possible. A wafer bump technique is a technique which forms a junction bump directly on the electrode pad of IC chip, and an imprint bump technique is a technique which carries out imprint formation of the junction bump at a lead. Although the electrode pad and the lead were joined by carrying out ultrasonic thermocompression bonding of an electrode pad and the lead through the bump formed with such a technique, since the photolithography technique was used for both these techniques, they had a resist coater, an aligner, and the problem that had to use an electrolytic plating system, a sputtering system, etc. further, and a bump formation process became very complicated, and a manufacturing cost also became high.

[0009] Then, the stud bump (nail heading bump) technique is proposed as a bump formation technique which solves such a trouble in recent years. junction of the shape of a ball which uses a wire ball bonding technique, without using a photolithography technique, and is formed in that technique although this technique is not different from the above-mentioned wafer bump technique at the point which forms the bump for junction directly on the electrode pad of IC chip -- public funds -- a bump is formed by the piece of a group.

[0010] Outline process drawing in the case of forming a bump in drawing 10 with this stud bump technique is shown. As shown in drawing 10 A, after fusing first the golden wire 107 which has come out from the tip of the capillary tube tool 103 by high-pressure discharge etc. and forming wire golden ball 107a, as shown in drawing 10 B, ultrasonic thermocompression bonding of the wire golden ball 107a is carried out to electrode pad 108a of the IC chip 108 arranged by the substrate 109. Next, as shown in drawing 10 C, a bump 113 is formed by pulling up the capillary tube tool 103 which clamped the golden wire 107 perpendicularly, and cutting the golden wire 107.

[0011] Thus, junction to electrode pad 108a of the IC chip 108 which has the formed bump 113, and the inner lead 115 formed in the TAB film 114 is performed by acting alignment as both correctly through a bump 113, and performing ultrasonic thermocompression bonding processing with a wedge 116 from superposition and on its, as shown in drawing 10 D.

[0012]

[Problem(s) to be Solved by the Invention] When the bump for junction was formed as mentioned above using a stud bump technique, in the above-mentioned process which

pulls up dispersion in a bump's height in the very minute range, pulls up the capillary tube tool 103 which clamped the golden wire 107 although it needed to control with a precision sufficient to **5 micrometers or less perpendicularly, and cuts the golden wire 107, such control had the problem of be very difficult. Moreover, the capillary tube tool 103 which needs a wire insertion part was also the cause which the load area which contributes to sticking-by-pressure deformation decreases considerably, does not come to earn a real plane-of-composition product enough, and spoils bond strength.

[0013] Furthermore, since near right above [of wire golden ball 107a by the side of the golden wire 107] was the recrystallization field influenced [thermal], it also had the problem of having a bad influence also on subsequent junction conditions. Moreover, although ultrasonic thermocompression bonding processing is performed in case a bump 113 is formed on electrode pad 108a of the IC chip 108 Furthermore, since 2nd ultrasonic thermocompression bonding is performed also in case electrode pad 108a and the inner lead 115 of the TAB film 114 are joined through the bump 113, the damage of the IC chip 108 becomes large. Moreover, there was a problem that will double since alignment is performed twice, and a gap will tend to become large, and the tact time like an erector will become more than twice.

[0014] Furthermore, in the former, there was a problem that equipment was enlarged and complicated for a nail heading bump's formation and lead junction since another tool of the capillary tube tool 103 and a wedge 116 is needed, respectively. Although ** also uses a wedge 116 as a fixture for ultrasonic pressurization heat-treatment in the case of junction to electrode pad 108a and the inner lead 115 of the TAB film 114 Since wire golden ball 107a which absorbs a supersonic wave at the time of use of this wedge 116 unlike the time of the 1st ultrasonic thermocompression bonding processing which forms the bump for junction, and makes buffer action does not exist The IC chip 108 tended to receive a damage, and there was a problem that a wedge 116 carried out wear deformation, and it was complicated.

[0015] It needed each to be maintained for the physical conditions of supply control of golden stroke material and ball formation and a machine, and an electric control network being complex and wide-ranging, and taking time amount to result in an adequate supply condition, and on the other hand, maintaining the conditions for stability in the equipment which carries out melting formation of the golden ball continuously, at a long period of time.

[0016] Therefore, the purpose of this invention is in the thing which height was controlled and was formed with high precision on the electrode pad of electronic-circuitry components, such as IC chip, and which offer highly precise and the bump formation approach which can form the bump of high quality.

[0017] In case other purposes of this invention join joint-ed material, such as an electrode pad which should join the lead of a leadframe, the inner lead of a TAB film, etc., and this lead, its bond strength is enough and they not only can make the damage to joint-ed material small, but are to provide with the junction approach the lead junction equipment list of electronic parts which can perform reliable lead junction.

[0018] The purpose of further others of this invention is to provide [the **** arrival of a metal ball, a nail heading bump's formation, and] the lead junction equipment list of electronic parts equipped with three functions with lead caulking junction with the junction approach.

[0019]
[Means for Solving the Problem] abbreviation prepared near adsorption opening prepared in a tube part for the lead junction equipment of the electronic parts by this invention to adsorb the spherical piece of a metal in order to attain the above-mentioned purpose, and the end section of the side which adsorbs the spherical piece of a metal of a tube part, and the adsorption opening -- it has the flat sticking-by-pressure formation section.
[0020] In 1 suitable operation gestalt of the lead junction equipment of the electronic parts by this invention, the end face of the end section arranges in parallel the 1st circle and 2nd circle, and is made into the shape of an ellipse which connected between the 1st circle and the 2nd circle at the flat surface, adsorption opening is prepared in the core of the 1st circle, and adsorption opening is not contained in the 2nd circle.
[0021] In 1 still more suitable operation gestalt of the lead junction equipment of the electronic parts by this invention, the core of the 2nd elliptical circle is formed in the place distant from the core of the 1st circle more than the path of the spherical piece of a metal in the end face of the end section.
[0022] The lead junction approach of the electronic parts by this invention Adsorption opening prepared in the tube part for adsorbing the spherical piece of a metal, and the end section of the side which adsorbs the spherical piece of a metal of a tube part, Consist of the flat sticking-by-pressure formation section, and the lead junction equipment of the electronic parts which have the inner skin of the shape of a taper to which is resembled, and is followed and a path decreases which separates from adsorption opening is used. abbreviation prepared near the adsorption opening -- The spherical piece of a metal is chosen from the group which consists of Metals Au, Ag, and Cu and eutectic alloy Au-Sn, Sn-Pb, and In-Pb, and it sticks to adsorption opening. The spherical piece of a metal to the member stuck by pressure thermocompression bonding or by carrying out ultrasonic thermocompression bonding The bump who has the projection of the shape of a back taper for carrying out sticking-by-pressure junction in the center is formed.
[0023] the hole of a lead of a TAB film is engaged with a bump's projection in 1 suitable operation gestalt of the lead junction approach of the electronic parts by this invention -- making -- abbreviation -- caulking sticking-by-pressure junction is carried out by the flat sticking-by-pressure formation section.
[0024] the abbreviation after forming a bump in 1 still more suitable operation gestalt of the lead junction approach of the electronic parts by this invention -- it is made to perform bump equalization which arranges a bump's height by the flat sticking-by-pressure formation section.
[0025]
[Function] According to the lead junction equipment of the electronic parts by this invention, the highly precise and spherical piece of a metal of high quality by which stable formation was carried out beforehand metallurgically is made to stick to adsorption opening of that end section. The joint-ed material which should join a lead and its lead by forcing superposition and the spherical piece of a metal from the top of the lead It is stuck by pressure by the flat sticking-by-pressure formation part. abbreviation which carried out package intensive sticking by pressure of a lead and the joint-ed material on the single point, and was further prepared near the adsorption opening -- Caulking sticking-by-pressure junction can be carried out, and while it not only can perform highly precise junction, but assembly can be simplified by 1 time of alignment, the damage by the

mechanical shock and heat cycle to joint-ed material can be stopped to the minimum.
[0026] Furthermore, since physical factors, such as supply control of golden stroke material and a ball process condition, and a machine and an electric control network are not made into ** at all, each maintenance for maintaining adequate supply at a long period of time can be excluded, and both the yield of a product and the operating ratio of equipment can be raised.
[0027] Moreover, it sets to the lead junction equipment of the electronic parts of this invention. The end face of the end section arranges in parallel the 1st circle and 2nd circle, and is made into the shape of an ellipse which connected between the 1st circle and the 2nd circle at the flat surface. abbreviation in which adsorption opening is prepared in the core of the 1st circle, and adsorption opening is not contained in the 2nd circle -- since the load area of sticking-by-pressure deformation can fully be obtained by having prepared the flat sticking-by-pressure formation section, the bonding strength of joint-ed material and a lead can perform high lead junction of sufficient reliability.
[0028] Moreover, in the lead junction equipment of the electronic parts of this invention, in the end face of the end section, since the core of the 2nd elliptical circle is formed in the place distant from the core of the 1st circle more than the path of the spherical piece of a metal, the spherical piece of a metal can be suitably adsorbed with adsorption opening in the 1st circle.
[0029] According to the bump formation approach for electronic-parts junction by this invention, the highly precise and spherical piece of a metal of high quality by which stable formation was carried out beforehand metallurgically is used. Make this spherical piece of a metal stick to adsorption opening of the end section of a capillary tube, and it carries out sticking-by-pressure deformation. the abbreviation highly minute on the electrode pad of electronic-circuitry components, such as IC chip, and after forming the bump of high quality, since bump equalization which presses by the flat sticking-by-pressure formation section, and arranges a bump's height can be performed It can use suitable for junction to the electrode pad of the electrode pad of electronic-circuitry components, such as IC chip, and printed wired board in a flip chip method.
[0030] Since the highly precise and spherical piece of a metal of high quality by which stable formation was carried out beforehand metallurgically can be used according to the lead junction approach by this invention By making this spherical piece of a metal stick to adsorption opening of the end section of a capillary tube, and carrying out sticking-by-pressure deformation The mechanical shock which joins this joint-ed material in case joint-ed material, such as an electrode pad which should join the lead of a leadframe, the inner lead of a TAB film, etc. and this lead, is joined is stopped. the damage -- the minimum -- it can stop -- moreover, the abbreviation for a capillary tube tool point -- since caulking sticking-by-pressure junction is performed in a flat part, high junction of reliability can be performed.
[0031]
[Example] It explains referring to a drawing hereafter, about the example which applied this invention, when joining the inner lead and outer lead of the electrode pad of IC chip, and a TAB film.
[0032] Drawing 1 is the important section perspective view of the ultrasonic thermocompression bonding equipment by the wire loess ball bonding method used in this example. As shown in drawing 1 , in this ultrasonic thermocompression bonding

equipment, the capillary tube tool 3 is being fixed to the beam 2 which built in the ultrasonic generator 1 with the conclusion screw 4. And the revolving shaft 5 attached in the tank of an ultrasonic generator 1 is supported at the both ends of a pedestal 6, the capillary tube tool 3 rotates centering on a revolving shaft 5 by this, and it is movable in the range where the capillary tube tool 3 is fixed.

[0033] Moreover, where the IC chip 7 which attached electrode pad 7a to the direct lower part of the capillary tube tool 3 is joined to a substrate 8, it is carried on heating apparatus 9, and the front face of the electrode pad 7a is heated by laying temperature. Furthermore, the pedestal 6 is constituted by X, Y, and the Z direction movable, and position control of the capillary tube tool 3 is carried out to the main right above section of electrode pad 7a, and it may have comes to descend at the time of sticking by pressure.

[0034] Next, the configuration of the junction equipment of the electronic parts by this example is explained. Drawing 2 shows an example of the bonding tool of the junction equipment of these electronic parts. Here, the expanded sectional view of the point of the capillary tube tool 3 and drawing 2 D of the sectional view where the important section top view of a bonding tool and drawing 2 B meet the A-A'line of drawing 2 A in drawing 2 A, and drawing 2 C are the important section expanded sectional views of drawing 2 C. As shown in drawing 2 , hole 2a is in the both sides of groove 2b, and is carrying out maintenance immobilization of the capillary tube tool 3 with the front conclusion screw 4 for the half moon which inserts the capillary tube tool 3 in a part for the point of a beam 2.

[0035] Hollow cylinder section 3a, 3t of tip taper sections, capillary tube section 3c, and 3d of ****** points are mutually open for free passage in the core of the capillary tube tool 3, and they are prepared in it. The closure of the upper part of hollow cylinder section 3a is carried out with the airtight lid 10. Moreover, ******** 3b is prepared in the top side of the capillary tube tool 3, and sealing fitting of the point 11a of the adsorption piping 11 is carried out to this ******** 3b. On the other hand, hollow exhaust-port 2c is prepared in that core at a beam 2, further, 2d of exhaust-pipe-arrangement openings and joint **** 2e are mostly prepared perpendicularly with this near [that] the tip, and sealing fitting of the other end 11b of the adsorption piping 11 is carried out to 2d of this exhaust pipe opening.

[0036] As shown in drawing 2 C and drawing 2 D, in 3d of ****** points of the capillary tube tool 3, 2 is continuously connected [3d of cylinder centrums which spread in the shape of a taper from capillary tube section 3c] with the corners 3e and 3f which intersect the level difference of a different path 1 and 3d of adsorption tip holes with a larger path than it. Moreover, that periphery consists of 3h of elliptical flat parts which connected the 1st circle which consists of the radius R which set the core O of 3g of sticking-by-pressure flat parts, and capillary tube section 3c as the core of a circle, and the 2nd circle of the radius R centering on the point P that only distance l separated from the core of this circle, at the band-like flat surface, and corner 3i is rounded. The distance l of the center to center of these 1st and 2nd circles is chosen as the relation of (l>D) to the diameter D of the metal ball 15.

[0037] Next, the outline of the approach the ultrasonic thermocompression bonding equipment constituted as mentioned above performs wire loess ball bonding is explained. First, the IC chip 7 of the high density which attached two or more electrode pad 7a beforehand joined to the substrate 8 is carried on heating apparatus 9, and it will be

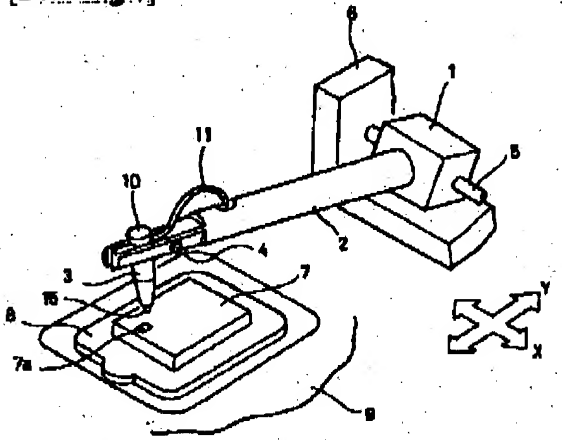
heated by predetermined temperature.
[0038] next, the bump formation prepared beforehand -- public funds -- supersonic vibration is intensively impressed from an ultrasonic generator 1 at the same time the point of the capillary tube tool 3 which is adsorbing the group ball 15 descends to a junction core and the metal ball 15 begins to deform by the load. Sticking-by-pressure deformation of the metal ball 15 is carried out by this, and a nail heading ball bump is formed of it.
[0039] Thus, the feed hole of the inner lead of a TAB film is made to engage with the formed nail heading ball bump, and on this, migration descent of the 3h of the elliptical flat parts of a capillary tube tool is carried out, it pushes, and sticking-by-pressure caulking is completed.
[0040] Drawing 3 A shows the detail of the point of the capillary tube tool 3, and expresses the condition that the end of capillary tube section 3c which has the metal ball 15 formed beforehand in the 1st [at the base of a point of the capillary tube tool 3 / elliptical] circle was adsorbed. Drawing 3 B is deformed for the metal ball 15 by which this point was adsorbed by thermocompression bonding or ultrasonic thermocompression bonding in the shape of a nail heading, the nail heading ball bump 16 shows the condition of having been joined to electrode pad 10a, the configuration of 3d of ****** points of the capillary tube tool 3 is imitated, and the nail heading ball bump 16 is formed.
[0041] Next, the bump formation process by this example and the lead junction process which follows it are explained, referring to drawing 4 and drawing 5 .
[0042] As drawing 4 shows the detail of the bump formation in the wire loess ball bonding by the ultrasonic thermocompression bonding equipment mentioned above and shows it first to drawing 4 A It sticks to capillary tube section 3c in the 1st [of the base which carried out the shape of an ellipse of the point of the capillary tube tool 3 for the metal ball 15] circle. The capillary tube tool 3 is positioned so that the capillary tube section which adsorbed the metal ball can descend in the center of electrode pad 7a of the IC chip 7 which separated fixed height in the direct lower part, and was installed on the substrate 8.
[0043] Next, as shown in drawing 4 B, the capillary tube tool 3 is dropped in the direction of an arrow head, by ultrasonic thermocompression bonding, sticking-by-pressure deformation of the metal ball 15 is carried out, and the nail heading ball bump 16 is formed. Then, as shown in drawing 4 C, the capillary tube tool 3 is raised in the direction of an arrow head. Thus, where press forming is imitated and carried out to the configuration of 3d of ****** points of the capillary tube tool 3, the nail heading ball bump 16 is formed on electrode pad 7a.
[0044] Drawing 5 shows the process of the lead junction approach by this example succeedingly carried out to bump formation. First, the bump 16 formed on electrode pad 7a of the IC chip 7 by the above-mentioned bump formation approach is made to engage with feed-hole 14a of the inner lead 14 of the TAB film 13. next, it is located in right above [of central height 16a of the bump 16 by whom the core of 3h of flat parts for performing caulking corresponding to the 2nd elliptical circle of capillary tube tool 3 base was made to engage with feed-hole 14a of an inner lead 14] from the condition which pulled up the capillary tube tool 3 right above [above-mentioned] after bump formation as shown in drawing 5 A -- as -- the capillary tube tool 3 -- a distance horizontally equal to l -- it is made to move

[0045] Then, as shown in drawing 5 B, the capillary tube tool 3 is dropped in the direction of an arrow head, by 3h of flat parts which perform caulking, the bump 16 made to engage with an inner lead 14 is pressed, and the sticking-by-pressure caulking 17 is formed. Then, as shown in drawing 5 C, the capillary tube tool 3 is raised. Thus, the sticking-by-pressure caulking 17 is formed from the nail heading ball bump 16.
[0046] At the time of sticking by pressure in this example, the sticking-by-pressure approach used with a conventional wire ball bonding technique, a conventional stud bump technique, etc. can be used. For example, the ultrasonic sticking-by-pressure approach which applies a pressure and is joined while making a supersonic wave act, and the ultrasonic thermocompression bonding which applies a pressure and is joined while making the thermocompression bonding approach which applies a pressure and is joined while heating, or a supersonic wave and heat act can be used suitably.
[0047] Moreover, since capillary tube section 3c of the capillary tube tool 3 in this example can make a path small as compared with the conventional thing, the sticking-by-pressure reduction of area of a metal ball is large and a large sticking-by-pressure load area can also be taken, bonding strength and quality can also be raised.
[0048] As a material of the metal ball 15, it can stick to conductivity and an endurance pan alternatively with the capillary tube tool 3, and the eutectic alloy chosen from the metal chosen from Au(s)(gold), Ag (silver), and Cu(s) (copper) excellent in workability or Au-Sn (tin), Sn-Pb (lead), and In(indium)-Pb can be used for them.
[0049] In addition, as a modification of this example, ******** is prepared in the airtight lid 10 and the adsorption piping 11 is connected to this ********. And the metal ball 15 is adsorbed at the point of this capillary tube tool 3 by exhausting the interior of hollow cylinder section 3a of the capillary tube tool 3 through the centrum of the airtight lid 10. Future processes are the same as an above-mentioned example.
[0050] Moreover, although the nail heading ball bump 16 formed of this invention has a precision of that height high enough as compared with what cuts the conventional wire, as long as it is required, she may be made to perform height equalization using 3h of sticking-by-pressure flat parts as another process.
[0051] This invention can be used also as a tool of not only the wire loess ball bonding method but the wire loess ball bonding method. Drawing 6 is used for the explanation in this case, and since an understanding is easy, formation of the nail heading ball bump 16 by the wire loess ball bonding method mentioned above is also shown in drawing 6 A and drawing 6 B.
[0052] Drawing 6 C shows the case where this invention is used, in order to perform bump formation by the wire ball bonding method. The metal wire 18 is inserted in capillary tube section 3c, and the wire metal ball 20 is formed at the tip. Next, as shown in drawing 6 D, after carrying out sticking-by-pressure deformation of this wire metal ball 22 by the point of the capillary tube tool 3 and moving the capillary tube tool 3 up, a wire is cut, and the nail heading wire bump 22 is formed by this.
[0053] As mentioned above, although the example which applied this invention when the inner lead and leadframe of the electrode pad of IC chip and a TAB film were joined was explained, this invention can be widely applied, not only a case such but when joining to an external circuit terminal, or when joining a minute lead and joint-ed material like [when carrying out flip chip bonding of the IC chip]. Moreover, there are two or more junction points, and also when it must join in the shape of SUTITCHI one after another, it

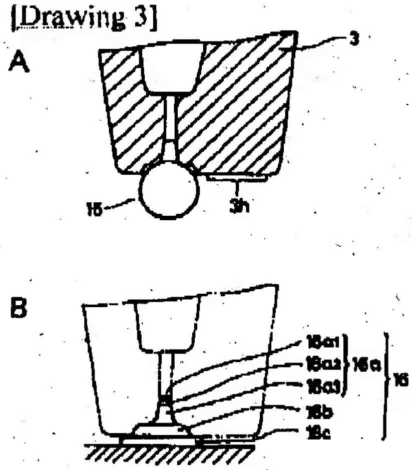
can apply.
[0054]
[Effect of the Invention] As explained above, according to the junction equipment of the electronic parts by this invention By [by which stable formation was carried out beforehand metallurgically] making highly precise and the metal ball of high quality stick to that point, and carrying out sticking-by-pressure deformation of this metal ball The bump of high quality can be formed, and highly minute on the electrode pad of electronic-circuitry components, such as IC chip, and in case joint-ed material, such as a leadframe and an inner lead of a TAB film, is joined, the damage to joint-ed material can be made small. Furthermore, highly minute and lead junction of high quality can be performed by carrying out caulking sticking-by-pressure junction of the nail heading bump who engaged with the feed hole of joint-ed material, such as a leadframe and an inner lead of a TAB film, by the same sticking-by-pressure flat part of the base of a tool.
[0055] Moreover, since this invention should just centralize load energy on a bump's central height in order to be able to take a large adhesive joint area of a lead and a bump and to carry out caulking sticking by pressure or bump equalization, since the flat part only for caulking is prepared in the capillary tube point, it can save load energy.
[0056] According to the junction equipment of the electronic parts by this invention, a supersonic wave can be absorbed through the metal bump who has buffer action without a capillary tube flat part's contacting a direct lead in the state of caulking sticking by pressure, the damage to IC chip can be reduced, and a capillary tube and the blemish to a lead, deformation, wear, etc. can be decreased sharply.
[0057] Since it is not the heat-treated weak wire ball according to the bump formation approach for electronic-parts junction by this invention, each bump height can be arranged for a bump's central projection produced when the shape of a nail heading is made to carry out sticking-by-pressure deformation by thermocompression bonding or ultrasonic thermocompression bonding on the electrode pad of electronic-circuitry components, such as IC chip, by the highly precise flat part at the tip of a capillary tube tool.
[0058] According to the junction equipment of the electronic parts by this invention, with the same tool, since three functions of central projection formation of the **** arrival of a metal ball and a nail heading bump and the lead caulking sticking-by-pressure junction just behind this are attained, another tool becomes unnecessary.

DRAWINGS

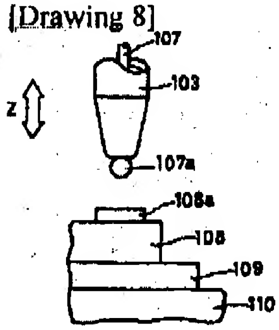
[Drawing 1]



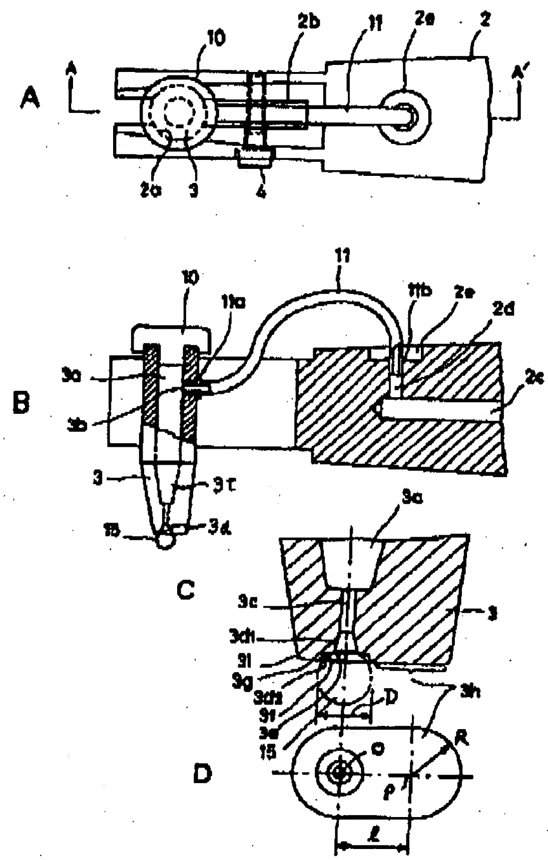
[Drawing 3]



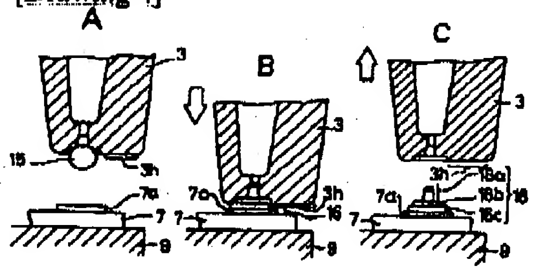
[Drawing 8]



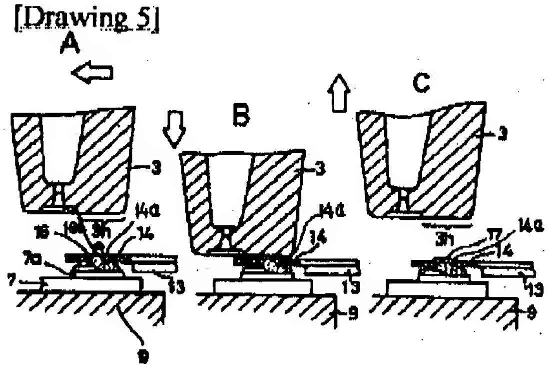
[Drawing 2]



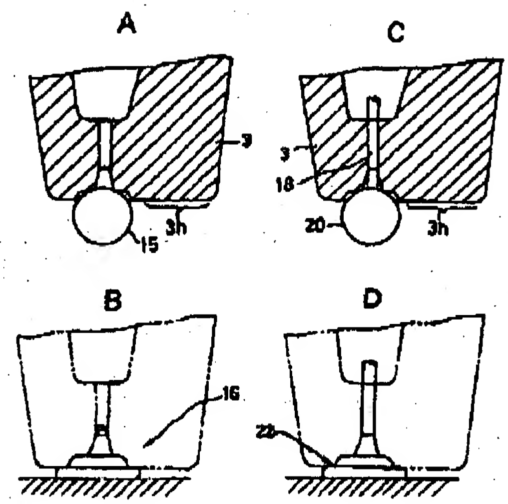
[Drawing 4]



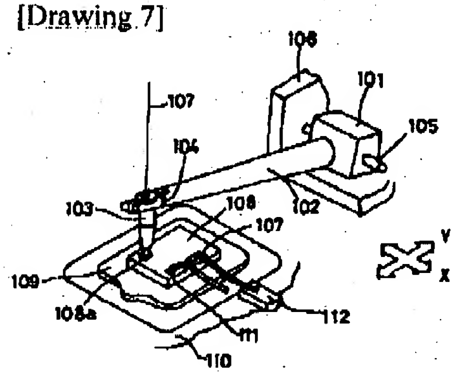
[Drawing 5]



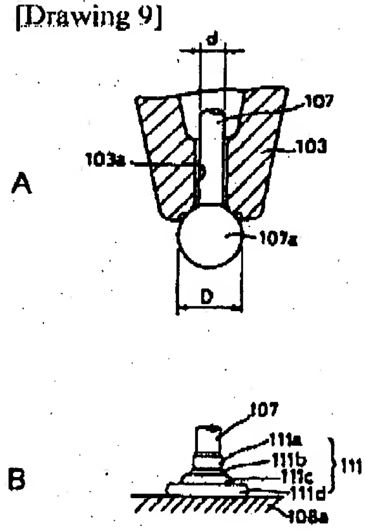
[Drawing 6]



[Drawing 7]



[Drawing 9]



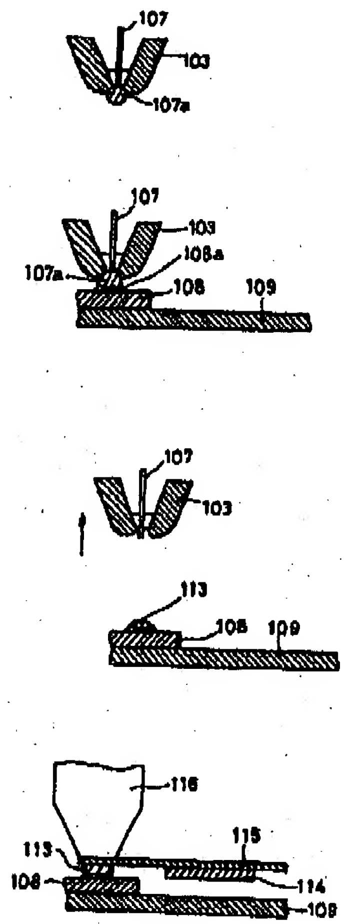
[Drawing 10]

A

B

C

D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Surface Mount Technology

Principles and Practice

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To my wife P
and my childr
the ones who

p. 349

Chapter 10
Metallurgy of Soldering and Solderability

10.0 INTRODUCTION

The solder used in electronic assembly serves to provide electrical and mechanical connections. In through-hole mount assemblies we had to worry primarily about obtaining sound electrical connections, because the plated through holes imparted sufficient mechanical strength. With the advent of SMT, the role of the surface mount solder joint has become very critical, because it must provide both mechanical and electrical connections. The solder joint strength is controlled by the land pattern design and a good metallurgical bond between component and board.

Surface mount land pattern design for providing adequate mechanical strength was covered in Chapter 6. In this chapter we concentrate on the metallurgical aspects of a reliable solder connection, as determined by the solder and the solderability of components and boards. A reliable solder connection must have a solderable surface to form a good metallurgical bond between the solder and the components being joined. An understanding of metallurgical bonding entails knowledge of phase diagrams, the concept of leaching, surface finish, wetting, oxidation of metallic surfaces.

Metallurgical phase diagrams are used to display the solubility limits of one metal into another and the melting temperatures for metals and their alloys, for a better understanding of intermetallic bonds. Phase diagrams can also be used for better understanding of leaching or dissolution phenomenan (of one metal into another). Finally, to produce solder joints in a cost-effective way, we need to know about the methods, requirements, and economics of solderability testing.

The focus of this chapter is on the practical aspects of metallurgical issues related to solderability of surface mount assemblies. The subject of soldering for surface mount assemblies is covered in Chapter 12. For an expanded coverage of basic metallurgical issues in electronics, refer to Wassink [1] and Manko [2].

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Chapter 12

Soldering of Surface Mounted Components

12.0 SOLDERING

Welding, brazing, and soldering processes for joining metals together differ basically with respect to the temperature at which the joining takes place. Welding is generally used for joining ferrous metals and is accomplished at high temperatures (1500–2000°F). Brazing is used for joining nonferrous metals at relatively lower temperatures (800–1000°F). Soldering, which is used mostly for electronic products, occurs at the lowest temperatures (400–500°F).

In all cases, either two similar metals are joined, or certain dissimilar metals or alloys. The joining mechanism is governed by the formation of intermetallic compounds between the metals to be joined. A basic knowledge of metallurgical properties and of phase diagrams is necessary for an understanding of the principles involved in joining. The metallurgy of soldering is discussed in Chapter 10. Now we focus on the processes and equipment used in this form of joining.

The earliest electronic products were hand soldered. In the 1950s hand soldering was replaced by the wave soldering process for mass soldering of through-hole components. Then in the 1970s, reflow soldering came into widespread usage for surface mount components. However, for surface mounting, depending on the component mix, both wave and reflow soldering processes are used.

The basic differences between wave and reflow soldering lie in the source of heat and the solder. For example, in wave soldering, the solder wave serves the dual purpose of supplying heat and solder. The source for the supply of solder is unlimited because the wave pot holds more than 500 pounds. In reflow soldering, however, solder paste is applied first in a predetermined quantity, as discussed in Chapter 9, and during reflow, heat is applied to melt (i.e., reflow) the solder paste. Thus a more appro-

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Curtailing Voids in Fine Pitch Ball Grid Array Solder Joints

by Gary Morrison and Kevin Lyne,
Texas Instruments Inc., Dallas, TX

ABSTRACT
Minor voiding in Ball Grid Array (BGA) solder joints is a common phenomenon, so these voids are not often considered to pose a vital threat to solder joint reliability. It has been found, however, that incorrect handling conditions can create open solder joints during reflow. This paper investigates some causes of voiding and open solder joints, and recommends ways to avoid them. Various design and assembly parameters have been studied to understand the phenomena. Several factors that affect the formation of voids are reported. The investigation reveals that the cause of void-induced open solder joints is primarily outgassing of moisture from components where proper handling precautions have not been observed. If proper handling precautions are followed, these components are shown to have none of the excessive voiding described.

INTRODUCTION
Surface Mount Technology (SMT) has evolved over the past decade from an art into a science, with the development of well-understood design and assembly guidelines. BGA components especially have been found to be robust and user-friendly devices. These packages merge readily into existing processes and reflow profiles. However, as the solder ball size and pitch decrease, the SMT design and assembly characteristics become more critical in controlling certain types of solder joint defects. Board Level Reliability (BLR) focuses on the complex interaction of various materials under the influence of ambient thermal experienced during the operation of the end equipment. In BGA components, the solder joint itself must be successful in accommodating:

- Cyclical strains due to expansion mismatches
- Warping and transient conditions
- Impact stresses
- Non-linear material properties
- Solder fatigue behavior influenced by:
  - Geometry
  - Metallurgy
  - Stress relaxation phenomenon
  - T mperature cycle conditions.

Solder joint voids are gen rally formed by pockets of gas trapped during the creation of solder connections between the component terminals and th Printed Circuit Board (PCB). Although voids may range widely in size and location, void formation may b classified into four main [1] types . Materials, Methods and machines, Environmental and Human factors. In this paper, we investigate some rather unique material and environmental factors affecting voids formed during the reflow process. The basic structure of the component studied in this report [2] is shown in Figure 1. It is a molded 0.8mm pitch BGA which uses a single layer metal pattern on polyimide tape. The solder balls are near eutectic. This package, called MicroStar BGA™, was developed at Texas Instruments for cost reduction and miniaturization. This component has been successfully surface mounted in high volume for nearly three years. As of July '99, more than 60 million units have been shipped. It is believed the phenomena studied in this paper are unique to this generic type of BGA, rather than specific to MicroStar BGA.

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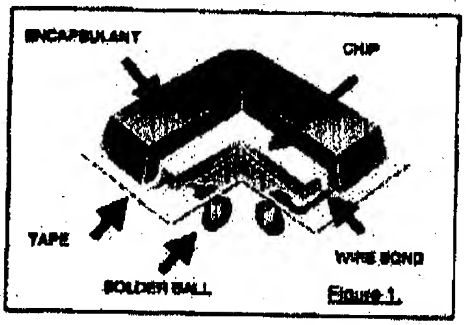


Figure 1.

Figure 1. MicroStar BGA™; is a trademark of Texas Instruments

MATERIALS AND METHODOLOGY

The experiments covered in this paper fall into two categories:

- Investigation and root cause analysis of board assembly variables that can create open solder joints immediately after the reflow operation.
- Examinations of measurable component variables that corroborate the root cause analysis.

In most cases, the experimental factors are greatly exaggerated or accelerated compared to normal conditions in order to generate time-zero failures or to shorten the time required for long-term failures to occur.

Underfill was not used in any of these experiments.

Visual inspection of solder joints, which was conducted after one or more reflows, consisted of microscopic cross- sectioning, SEM or transmission x-ray techniques. Image analysis software was not used in this report, so the visual techniques have a only a qualitative value.

The BLR testing is based on non in-situ electrical monitoring of daisy-chain components assembled to a special PCB. Electrical measurements are made in the initial state and then at intervals of 100 temperature cycles. The daisy-chained units are made using the standard assembly process including the silicon chip and gold bond wires. When a daisy-chain d package is assembled on the PCB, a

complete circuit is formed which allows continuity testing. The circuit includes each solder ball, the metal pattern on the die, the bond wires and the PCB traces.

SOLDER PASTE

Solder paste is recommended when mounting fine pitch BGAs for four basic reasons[3]:

- It acts as a flux to aid wetting of the solder ball to the PCB land.
- The adhesive properties of the paste tend to hold the component in place during reflow.
- It helps to compensate for minor variations in the planarity of the PCB or solder balls.
- Solder paste contributes to the final volume of solder in the joint and allows the total volume to be optimized.

Paste selection is normally driven by overall assembly requirements. In general, the "no clean" compositions are preferred due to the difficulty in cleaning under the mounted component. Most assembly operations have found that no changes in existing pastes are required by the addition of fine pitch BGAs to a PCB, but due to the large variety of board designs and tolerances it is not possible to say this will be true for any specific application.

Nearly as important as paste selection is stencil design. A proactive approach to stencil design can pay large dividends in assembly yields and lower costs. The typical stencil hole diameter is the same size as the pad area, and 125 to 150um thick stencils have been found to give the best results. Good release and a consistent amount of solder paste and shape are critical, especially as ball pitches decrease. The use of metal squeegee blades, or at least high durometer poly blades, is important in achieving this. Paste viscosity and consistency during screening is another variable that requires control.

REFLOW

Solder reflow conditions are the next critical step in the mounting process. During reflow several things occur in short time span [4]:

- The solvent in the solder paste evaporates.
- The flux cleans the metal surfaces.
- The solder particles melt.
- Wetting of the surfaces takes place by wicking of molten solder.
- The solder balls collapse.
- The process is completed with the solidification of the solder into a strong metallurgical bond.

The desired result is a uniform solder structure strongly bonded to both the PCB and the component, with minimal voiding and an even fillet at both ends. Conversely, when all the steps do not carefully fit together, major voids, gaps, uneven joint thickness, discontinuities and insufficient fillet can occur. While the optimum reflow cycle depends on the system and paste composition, there are several key points all successful cycles have in common.

The first of these is a warm-up period sufficient to safely evaporate the solvents. This can be done with a pre-heat or bak , commonly reflected as a hold tim in the cycl at evaporation temperatures. If there is less solvent in th paste (such as high viscosity and high

metal content paste), th n the hold can generally be shorter. However, if the hold time is not long enough solder splatter can occur. Secondly, successful reflows commonly have uniform heating across the component and PCB. Uneven thickness and non-uniform solder joints may be an indication that the profile needs adjustment. There can also be a problem when different sized components are simultaneously reflowed. Care needs to be taken when profiling an oven to be sure that the indicated temperatures are representative of what the worst case components experience. This concern is heightened with infrared (IR) reflow.

In summary, successful reflow cycles strike a balance among temperature, timing and length of cycle. Poor timing may lead to oxidation, excessive voiding, premature paste dry-out, poor wetting and splattering. Some process development is advisable to guarantee a good process window for each paste and reflow combination. Extremely fine tuning of existing profiles are driven by the interplay of such factors as solder paste particle size, flux activity, metal percentage, ramp rates, peak and hold temperatures, board construction and atmosphere.

OTHER REFLOW ISSUES

While fine pitch BGA components offer improved board- level manufacturability, throughput and yield compared to larger components, there are some factors to keep in mind, especially as the ball pitch decreases. One item of special attention is the moisture sensitivity. Manufacturers normally specify the moisture sensitivity level for each type of component and it is important to respect these conditions. The time out of a dry environment should be controlled according to the label on the packing material or other specifications. This will prevent excessive moisture absorption, which can lead to solder joint defects as discussed later in detail. Also, the PCB may twist and bow during reflow. This problem becomes more pronounced as PCBS decrease in thickness. Potential problems from this effect may show up as mis-aligned and mis-formed solder joints, or other discontinuities. Proper support of the PCB through the furnace, balancing the tab attachments to a panel, and even using a weight or fixture to stiffen the PCB may be worth investigating.

EXPERIMENTATION AND RESULTS

In order to investigate thoroughly the effects of exposure to high moisture levels and different types of reflow, several individual experiments were conducted. The component studied, the 64-lead MicroStar BGA, has been qualified by Texas Instruments to JEDEC Moisture Level 3 at both the component and the board level [5]. See Table 1. The board level reliability testing was conducted by non in-situ electrical monitoring of daisy-chain resistance components, as shown in Figure 2, mounted to a daisy- chain PCB design as represented in Figure 3. Electrical measurements made in the initial state and then at intervals of 100 temperature cycles. The daisy chained units are made using the standard assembly process including the silicon chip and gold bond wires. When a daisy-chained package

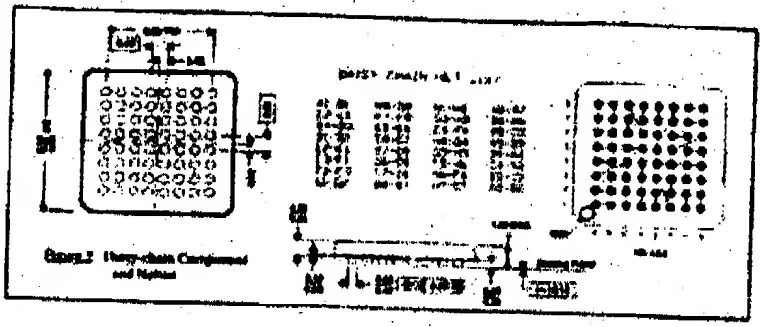


Figure 2 Daisy-chain Component and Netlist

Table 1.

Component qualification data on the 64-lead MicroStar BGA			
Test Requirement	Conditions	Read points	Sample/ Fail
1 Steady-state life	140C	500 Hr	140/0
2 Biased humidity	85C, 85% RH	1000 Hr	120/0
3. Autoclave	121C, 15 psi	240 Hr	225/0
4. Temp cycle	-65/+150C	1000 Cy	348/0
5. Temp cycle	-40/+125C	1000 Cy	140/0
6. Temp cycle	-55/+125C	1000 Cy	348/0
7 Thermal shock	-65/+150C	1000 Cy	348/0
8. Storage life	170C	420 Hr	135/1
9. BLR	-40/+125C	1100 Cy	85/0
10. Physical dimension			15/0
11. Flammability	Method A		15/0
12. Electrical Characterization			150
13. Wirebond strength			220/0
14. X-Ray			15/0
15. Visual			1848/0
16. Solvent resistance			36/0
16 Solderability	8 Hr steam		66/0

Note: The component-level stress tests were pre-conditioned, and the product was qualified to moisture sensitivity level 2 (JEDEC A113). The board-level test was pre-conditioned, and this product was qualified to moisture sensitivity level 3 (JEDEC A113).

Pads: SMD, 300um dia. pad and 350um dia. opening

Paste: 150um thick, 63Sn eutectic

Reflow: Air, 235C peak

Figure 3. BLR test board (TB) Material: FR-4, Top Cu with Au/Ni plate. Size: 150 x 250 x 0.8mm
Temperature cycle: Ramp: 2 to 3 minutes. Dwell: 13 to 13 minutes. Full cycle: 30 minutes
Test: Continuity @ 125C, less than 200 Ohms or 10% resistance change

is assembled on the PCB, a complete circuit is formed which allows continuity testing. The circuit includes each solder ball, the metal pattern on the di , the bond wires and the PCB traces.

Table 2 contains a summary of the materials, conditions and results from our study of various reflow conditions. The samples were tested with electrical and visual inspection. The results were as expected for conventional reflow systems. The vapor phase (VP) reflow system here is used as a reference, since it is not found in most assembly houses. In the case of IR reflow systems; failures were detected in low levels. IR reflow furnaces

Table 2. Effect of Reflow Type on Solder Joints

64-lead Package Open Solder Joints / Sample Size			
Moisture Level	Convection reflow[1]	VP reflow	IR reflow[2]
L4	—	0/635	0/100
L3	0/231	—	0/132
L2a	0/234	—	—
L2	—	0/164	1/133
L1	—	—	1/154

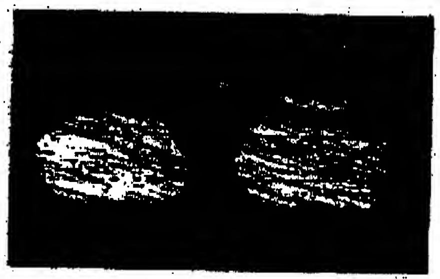
1. Forced convection (air). Peak temp. 230C
2. Infrared furnace (air). Non forced convection. Peak temp. 245 C

are rarely found in production today, although many customers use IR reflow for prototyping or one-shot assemblies.

OBSERVATIONS

A micro-cross section photo representative of the open solder joints found in this test is shown in Figure 4. It can be seen that the solder ball does not completely de-wet from the component, but simply separates, leaving a wetted solder surface. The break occurs within the bulk of the solder joint near the "neck". This is the area where the solder ball joins the component through an opening in the tape. This experiment indicates that the combination of IR reflow and high moisture level exposure can create low levels of open solder joints.

FIGURE 4. An open joint after IR reflow, level 1 or 2



Open solder joint Good joint

Figure 5. High magnification photo showing the edge of an open solder joint and the delamination pathway in the via. This occurred after improper moisture handling and IR reflow.

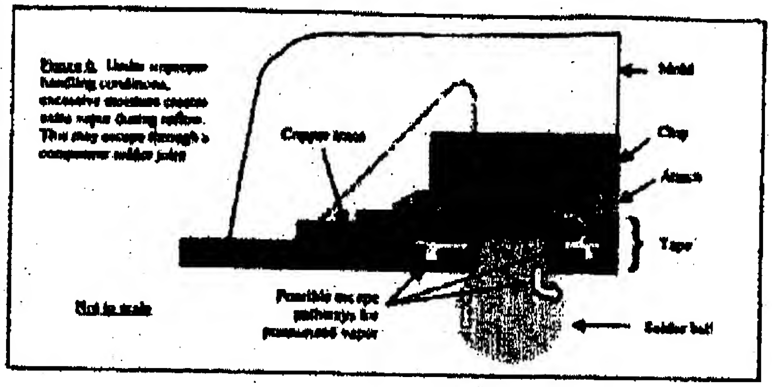
On the rare occasion that an IR system is used, it is likely to be in a prototype or engineering development environment. In this type of situation, moisture content is more difficult to control since the components are usually exposed to engineering time lags not found in production. In this respect, the use of IR reflow is problematic unless special attention paid to controlling the moisture level per the manufacturer's specification.

ANALYSIS

Although this phenomenon is the result of improper handling conditions, it is desirable to find the root cause so as to understand the pre-cursors and possible side effects. To this end, other inspection techniques were used to narrow-in on the area of the open solder joint.

Figure 5 shows a high magnification cross section in the area of a failing joint. A detailed examination of these results and photos indicate the probable root cause to be outgassing of moisture within the package during reflow. The mechanisms appear to be as follows:

- If the moisture sensitivity recommendation has not been respected, excessive moisture absorbed into the package can vaporize, and seek an escape pathway to the outside of the package.
- The moisture is vaporized under pressure, so the temperature at which this occurs is somewhere above 10OC. Empirical evidence suggests that this occurs when the solder is in the molten state. In some cases, the vapor escape pathway can lead to a solder ball connection on the package.
- As the high-temp vapor enters the component solder via, it may escape from the via. For example, down the sidewall, leaving the solder joint intact.
- Alternative y, the vapor may create an open solder j oint by displacing molten solder in the joint. This seems to occur under certain conditions:
    - o The solder is softened to some degree such that the vapor may create a break in the joint.
    - o After the break, as the solder reflows, the two separated sold r surfaces do not combine to reform the original joint. This could be due to a lack of sold r volume (if solder has been spat away from the joint), or due to oxidation effects on the separated surfaces. A diagram illustrating this mechanism is shown in Figure 6.



FOLLOW-UP EXPERIMENTS

Additional experiments were conducted to corroborate the analysis suggested above. The focus in this area was to identify some measurable factors that should follow from the premise and to verify these.

As mentioned earlier, we expected that the grade of the seal formed by the via opening and the molten solder would depend to a large extent upon the geometry. One easily measurable factor in this system is the initial solder ball diameter. With this in mind, we investigated the effect of initial solder ball size on open solder joints in the uncontrolled conditions described above.

The results may be found in Table 3. As seen, the largest solder ball size did increase the level of opens. As expected, a larger volume of solder covers the via opening more completely, thus providing a stronger seal against the molten solder collapsing back into the via. In this table, the .60mm diameter solder ball clearly shows some effect. In addition, a small solder ball will permit the escape of vapor around the ball without displacing

Table 3. Effect of solder ball size on open solder joints created by exposure to moisture greater than level 2 or 3 followed by IR reflow.

Solder Ball Diameter[1] Open Solder Joints / Sample Size			
0.40mm	0.45mm	0.50mm	0.60mm
3/3497	1/3497	1/2499	34/1458

1. 144-lead package, 0.8 pitch, 0.375 diameter via opening.

solder and disrupting the joint. A large solder ball tends to trap escaping moisture, thus increasing the tendency of the vapor to displace solder in the via area, creating the open joint. However, it is not advisable to select a precise optimum solder ball size from this specific experiment for three reasons:

- The diameter of the via openings vary among components. This table is based solely on a via opening of .375mm diameter.
- Since only four different sold r ball sizes were examined, the resolution is not great enough to select an optimum solder ball

size.
Finally, th thickness of solder paste on the PCB varies among applications. The solder in this paste contributes to the overall solder volume and will change the solder ball size during reflow.

Another area investigated was the moisture characteristics of the materials in the component. The results from these measurements are listed in Table 4, The materials were measured in amounts proportiona to those found in the overall component This clearly indicates that a relatively greater amount of moisture is absorbed by the substrate materials and the chip attach material. This supports the root cause analysis presented earlier, since the prominent vaporized moisture pathway appears near these interfaces.

CONCLUSIONS

The precise extent to which the individual effects described above occur, and the extent to which they are related, is not known in a quantitative way. However we have drawn some general conclusions based on the empirical evidence and supporting opinions.

- Investigations conducted on fine pitch BGAs, including the MicroStar BGA, have demonstrated 100% board assembly yield and acceptable thermal cycling results even with some inconsistencies in the solder paste process[6].
- No open solder joints were observed when the proper handling precautions were followed. Always adhere to the manufacturer's specification regarding the JEDEC moisture sensitivity level.
- IR reflow is clearly more sensitive to this phenomenon. When using IR reflow, special attention must be paid to controlling the moisture level.
- An extra large volume of the solder in the joint during reflow tends to increase the number of open solder joints under these inappropriate conditions. However, the proper amount of solder volume varies among components. In this case, the initial solder ball should be less than 0.60mm diameter.

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Guidelin s for Sold ring Surface Mount Components to PC Boards

Technical Brief October 2000 TB334 2

Author: Maury Rosenfield

Introduction

The most commonly used techniques for mounting SMDs (Surface Mounted Devices) to PC boards are Infrared (IR) and Vapor Phase (VP) reflow. IR and VP reflow are preferred over wave soldering. Wave soldering typically involves increased heating rate, higher temperatures and increased flux exposure. **If wave soldering is to be used as a reflow method, Intersil must be contacted prior to use.** (See Technical Brief TB363, "Guidelines for Handling and Processing Moisture Sensitive Surface Mount Devices (SMDs)).

The dynamics of the reflow process are influenced by the type of equipment used. The variables involved must be understood to properly control the board level interconnection of SMDs.

The primary phases of the reflow process are: flux activation, melting the solder particles in the solder paste, wetting the surfaces to be joined, and solidifying the solder into a strong metallurgical bond.

Optimum fusing of the component leads with the solder paste on the board is achieved when the leads attain the melting temperature of the plated solder alloy. To avoid thermal shock of the SMDs the maximum heating and cooling rates (i.e., ramp rate) should be controlled.

IR Reflow

The IR reflow technique involves thermal energy supplied via lamps radiating at a given range of wavelength. This heating approach in its basic form is essentially a line-of-sight surface-heating technique. Therefore, the amount of thermal energy absorbed varies with board size, component size, component orientation, and materials used. The surface temperature of the board is not uniform throughout and board edges tend to run 10°C to 20°C higher than the center. If not properly planned, component overheating is possible.

Vapor Phase Reflow

The vapor phase reflow technique uses vapor from a boiling inert fluorocarbon liquid. The heat of condensation provides a thermal constraint dependent on the liquid selected. A typical material in the industry has a boiling point of 215°C. PC board temperature exposure should be very uniform. With essentially no temperature gradient across the surface of the board, component location design rules for even heating is not significant compared to IR reflow.

Solder Profile Development

Heating Rate - To avoid thermal shock to sensitive components the maximum heating rate should be controlled. It is desirable t hold the heating rate to l ss than 5°C/s.

Preheat Zon - Boards should b preheated prior to the r flow step. Over-baking the sold r paste and exce ding the glass transition temperature of the epoxy in FR-4 boards should be avoided. Depending on the type of IR or VP equipment, the temperature of the component and the PC board should be within the range from 105°C to 145°C.

Time above Solder Melting Point - It is recommended that th solder at the joint be kept above its melting point for sufficient time to flow and wet the lands and the leads. Depending on type of equipment and component size; time above 180°C could range from 10s to 150s. Extended duration above the solder melting point may damage the board and sensitive components. This value should be minimized but sufficient to allow for good solder joint formation.

Peak Reflow Temperature - The peak temperature of the solder joint during reflow should be high enough for adequate flux action and solder flow to obtain good wetting. The maximum peak temperatures for IR and VP reflow are 219°C/225°C or 235°C/240°C, depending on package dimensions (Refer to J-STD-020A). Residence time at peak temperatures should be minimized.

Cooling Rate - The cooling rate of the solder joint aft r reflow is important because the faster the cooling rate, the smaller the grain size of the solder, and the higher the fatigue resistance. However, care should be taken to avoid an excessive temperature gradient resulting in potential damage due to mechanical stress.

Summary of Soldering Precautions

The soldering process can create a thermal stress on any semiconductor component. The melting temperature of solder is higher than the maximum rated temperature of the device. The amount of time the device is heated to a high temperature should be minimized to assure device reliability. Therefore, the following precautions should always be observed in order to minimize the thermal stress to which the devices are subjected.

1. Always preheat the device.
2. The delta temperature between the preheat and soldering should always be less than 100°C. Failure to preheat the device can result in excessive thermal stress which can damage the device.
3. The maximum temperature gradient should be less than 5°C per second when changing from preheating to soldering.
4. The peak temperature in the soldering process should b at least 30°C higher than the melting point of the solder chosen.
5. After soldering is complete, forced cooling will increase the temperature gradi nt and may result in latent failure due to mechanical str ss.
6. During cooling, mechanical stress or shock should be avoid d.

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